EXHIBIT B

CAB-O-SIL® Fumed Silica in Adhesives & Sealants

This brochure provides you with information about the reinforcing and rheology control properties of fumed silicas in adhesive and sealant systems. Proper dispersion methods are discussed, along with the rheological properties of shear thinning, recovery rate, thixotropy and extrusion rate. Data compares the performance of fumed silica with several competitive materials in an RTV-1 silicone sealant, a two-part epoxy adhesive and a one-part moisture curing urethane sealant.

TD-103 web.
[Size: 2,187

For additional information, see CAB-O-SIL LM-150 and CAB-O-SIL LM-150D.

Do you have additional questions or require additional technical information? Be sure to use CABOTech, our online Technical Service answering system for registered users of our website.

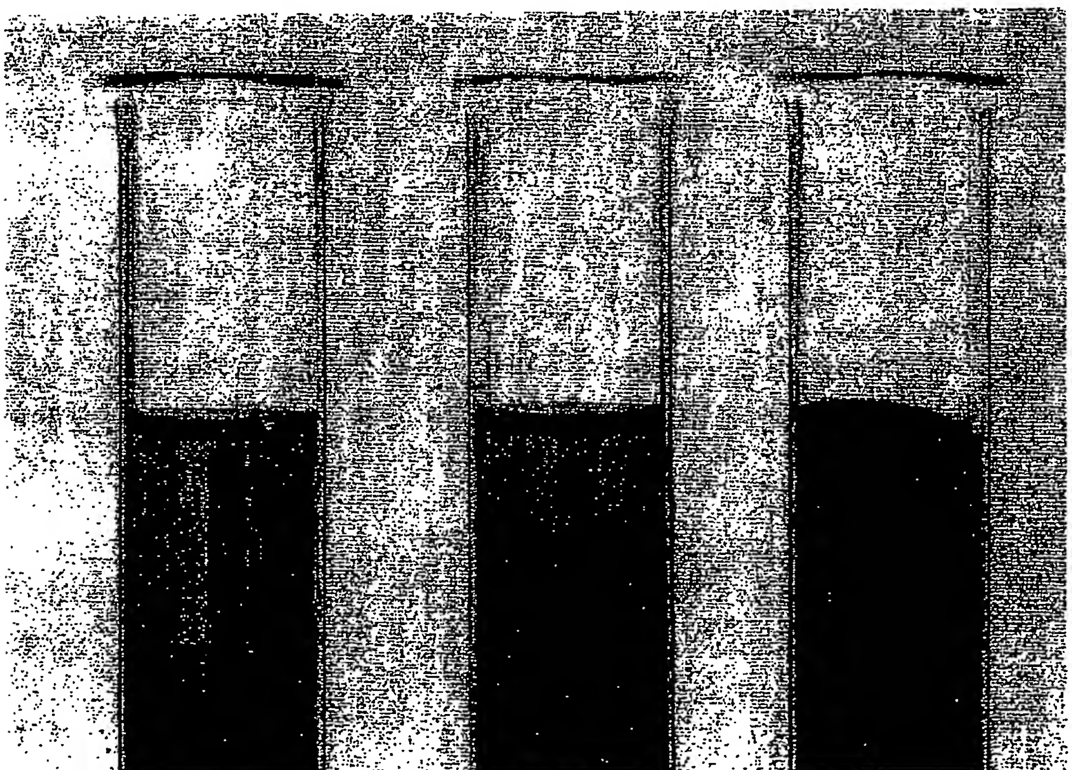
Introduction

CAB-O-SIL® fumed silica is a versatile, efficient additive used by adhesive and sealant manufacturers to achieve desirable performance characteristics in their products. This fine white powder is an important ingredient in many systems including epoxies, silicones, polyurethanes, polyacrylics, polysulfides, butyl rubber, etc.

CAB-O-SIL fumed silica is used to impart five major properties in adhesives and sealants:

1. Flow control, including thickening and thixotropy
2. Anti-settling during storage (Figure 1)
3. Extrusion control during application
4. Anti-sag during cure (Figure 2)
5. Reinforcement, such as to improve tear strength of the cured sealant (Figure 3), and cohesive and adhesive properties of cured bond (Figure 4).

The combination of CAB-O-SIL fumed silica's unusually small particle size, tremendous surface area, purity and chain-forming tendencies makes this product very unique among adhesive and sealant additives.

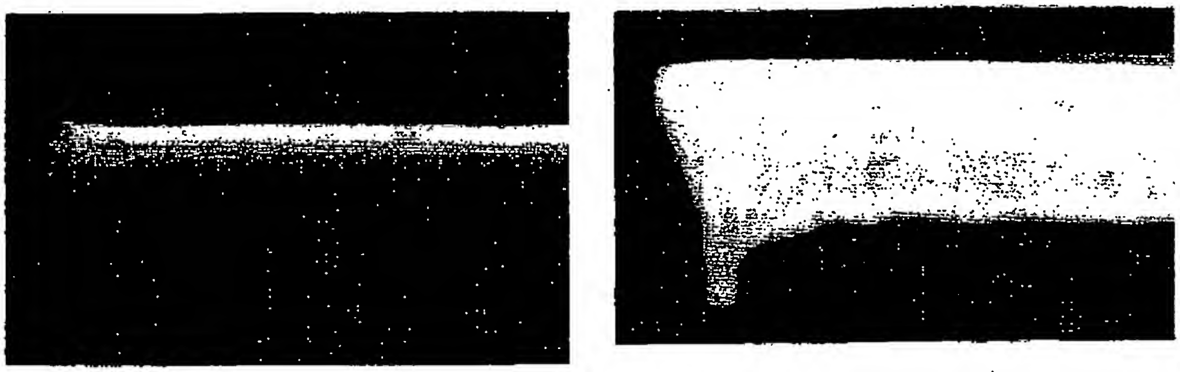


A) No thixotrope. Severe settling.

B) 2 wt. % CAB-O-SIL M-5 fumed silica. Partial settling.

C) 2 wt. % CAB-O-SIL TS-720 fumed silica. No settling.

Figure 1: Comparison of the settling of iron powder in an epoxy patching compound



A) CAB-O-SIL TS-720 treated fumed silica B) CAB-O-SIL M-5 fumed silica

Figure 2: Sag properties of epoxy resin sealants after accelerated aging for 4 weeks at 60°C prior to cure

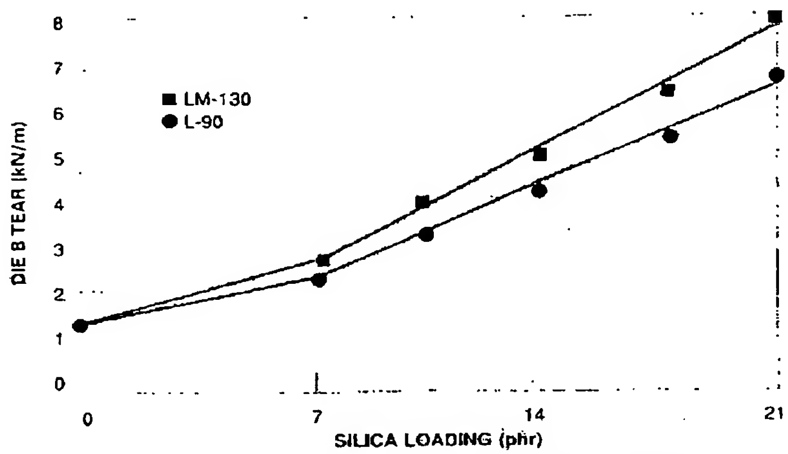


Figure 3: Tear resistance as a function of CAB-O-SIL fumed silica loading in a silicone sealant

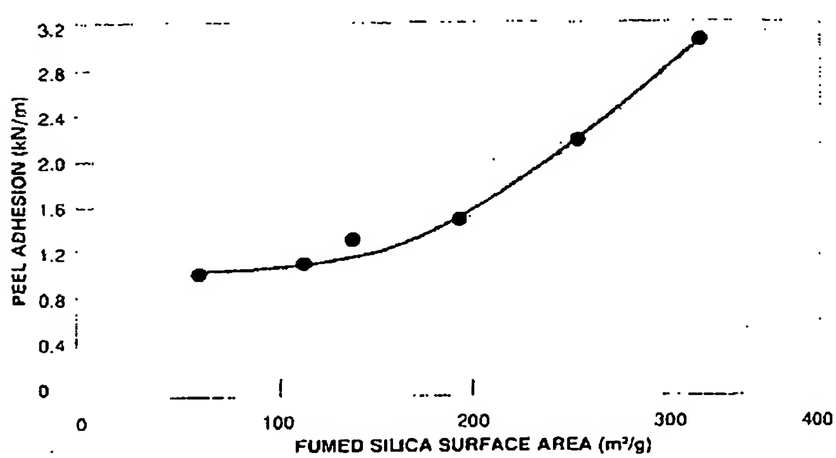


Figure 4: Effect of CAB-0-SIL fumed silica surface area on peel adhesion

Reinforcement Properties

CAB-O-SIL®fumed silica is a very effective reinforcing agent for crosslinked polymer systems. This is partly the result of the very large surface area available for polymer/filler interaction due to the small particle size and open branched chain nature of the silica aggregates. For example, a silicone rubber RTV-1 sealant containing 10 percent by weight of a 200 m^2/g CAB-O-SIL would have approximately 20 square meters of silica surface for polymer/filler interaction per milliliter of sealant.

The second factor is the reactivity of the surface. Untreated surfaces contain many surface silanol groups which can strongly interact with polymer molecules primarily through hydrogen bonding and van der Waals forces. Treated silicas normally interact more weakly with polymer molecules as their remaining surface silanol groups are shielded by the larger organosilicon surface groups, and hence the primary interaction is via the weaker van der Waals forces as shown in Table 3.

TABLE 3

EFFECT OF TREATED AND UNTREATED SILICAS ON CURED PHYSICAL PROPERTIES OF A SILICONE RUBBER RTV-1 SEALANT

Formulation	1	2	3
CAB-O-SIL fumed silica type		LM-130	TS-720
Level (phr)	—	14	14
Cured Physical Properties			
Shore A Durometer	7	20	16
Die B Tear, kN/m (ppi)	1.2 (7)	5.1 (29)	4.2 (24)
Modulus @ 50% MPa (psi)	0.13(20)	0.32 (45)	0.29 (40)
Tensile, MPa (psi)	0.32 (45)	1.51 (210)	1.02 (150)
% Elongation	330	460	320

Dispersion

Normally, for either type of product, increasing the bulk density of the CAB-O-SIL® fumed silica from approximately 2.5 lbs./cu. ft. pour density (40-50 g/l tap density) to 5.0 lbs./cu. ft. pour density (105-135 g/l tap density) will increase the rate of incorporation, but decrease the ease of dispersion. If the mixing equipment used is a low shear type and the viscosity of the system is low, then incomplete dispersion of the silica may result, causing the system to fail to develop good theological and cured physical properties. In addition, undensed high surface area grades of CAB-O-SIL require high shear mixing equipment for optimum dispersion so that their superior theological and reinforcement properties can be fully developed.

There are many types of mixers used to manufacture adhesives and sealants. Normally, the cost of mixers is very significant. Hence, the choice of a particular CAB-O-SIL fumed silica grade is often related to the type of mixer used by the formulator. You must match the dispersion capability of your mixer to the dispersion characteristics of the grade of CAB-O-SIL.

A list of the types of mixers commonly used in the manufacture of adhesives and sealants is given below:

	Adhesives	Sealants
Increasing Dispersion Capabilities ↓	Change can	Dough mixer
	Dispersator blade	Low shear change can
	3 roll mill	High shear change can
		Twin screw extruder mixer

Normally, undensed grades of CAB-O-SIL fumed silica are used with adhesives and sealants, except in the case of the use of twin screw extruders, where the rate of wet-in of the silica is of critical importance to throughput. The main grades of CAB-O-SIL being used are those with surface areas 100-200 m^2/g. As a rule of thumb, the lower shear the mixer, the lower the CAB-O-SIL fumed silica surface area required to get optimum dispersion and cost performance from the silica.

In moisture-cure systems, an additional benefit of the lower surface area grade CAB-O-SIL silicas and the treated grades is their low moisture content. The moisture content of the CAB-O-SIL fumed silica should be <1.0% by weight for use in silicone rubber and polyurethane systems. The low moisture level is essential to prevent premature curing of the adhesives and sealants in the tube prior to use.

The order of addition to the product mix is also important. Usually, the CAB-O-SIL is added to the system after the polymer and liquid diluents have been mixed together but before the addition of special additives and the crosslinker. When used in sealants, the CAB-O-SIL fumed silica is added in several portions, allowing each portion to wet-in and disperse prior to the next addition. The exceptions to the order of addition rule are when using alkyl triacetoxy silanes and amine crosslinkers in silicone rubber RTV-1 systems where the crosslinker should be added prior to the CAB-O-SIL fumed silica.

The level of CAB-O-SIL required to impart optimum desired theological and reinforcement properties to an adhesive or sealant depends on the chemistry and composition of the system. Typically, silica loadings for adhesives are 1–6% by weight and for sealants are 3–12% by weight.

Rheological Properties of Adhesives and Sealants

An ideal adhesive or sealant should have the theological properties shown in Figure 18. If a force (stress) is applied to an adhesive or sealant, no flow of the material will occur until a certain stress level is reached. This value is called the yield point. This parameter can be correlated with the sag resistant properties of the adhesive or sealant. The higher the yield value, the better the sag resistance of the adhesive or sealant. As the stress is increased further, the system begins to flow and will exhibit thixotropic behavior such as shown by the flow curves. The greater the shear stress applied, the greater the shear strain or movement of the system and the lower the measured viscosity, line A-B. As the shear stress is lowered, the CAB-O-SIL®silica network partially reforms and the viscosity of the system increases, line B-C. There is a time lag in the complete rebuilding of the network which is the reason for the failure of the lines AB and BCA to be coincident. This time lag is called the recovery rate. In fact, the sag resistant properties of the system are related to the yield value and the rate of recovery of the network after the material has been sheared during application, e.g. extrusion, brushing or spraying. The ideal adhesive or sealant should have a high yield point with a high shear thinning index and a fast recovery rate.

The theological properties of adhesives and sealants can be determined using standardized test methods. The anti-sag properties of sealants can be measured using the Boeing slump test (ASTM D-2202) or the Canadian Standard CGSB19-GP-5 drainage test. For adhesives, the Leneta anti-sag meter test (ASTM D4400) gives good results. The extrusion properties of sealants are measured using MIL Specification 7502 (ASTM C731) through a 3.17 mm nozzle at various pressures.

The flow properties of adhesives and sealants are frequently measured using a Brookfield viscometer, where the viscosity is measured at two different spindle speeds at a rotation ratio of 10:1, if possible, as shown in Figure 19. The ratio of the viscosity measured at the low spindle speed to the high spindle speed is termed the shear thinning index and is a measure of the shear sensitivity (or pseudoplasticity) of the adhesive or sealant. Although attempts are sometimes made, it is impossible to predict the anti-sag properties of the system (the theological properties of the system at rest after shearing) to those of the system during flow, i.e. extrusion rate, viscosity. The latter parameters are measured at much higher shear rates than for sag measurements which are measured at a shear rate of essentially 0 sec^{-1}.

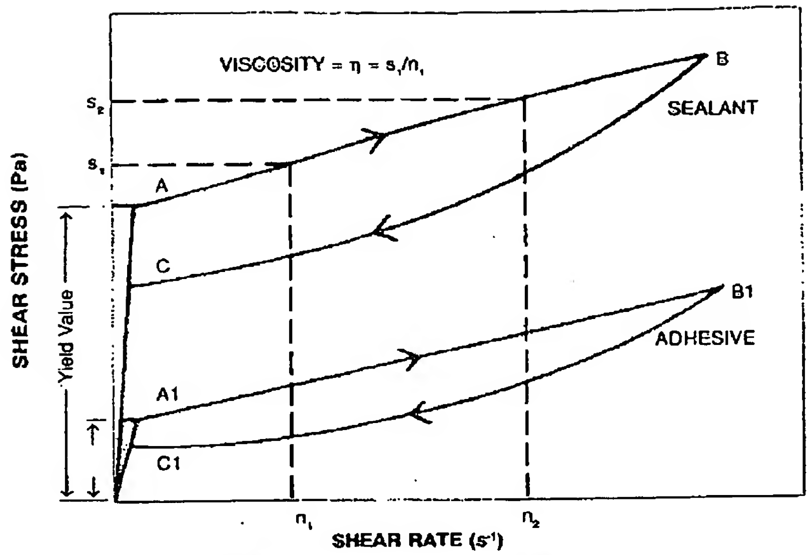


Figure 18: Rheological properties of adhesives and sealants

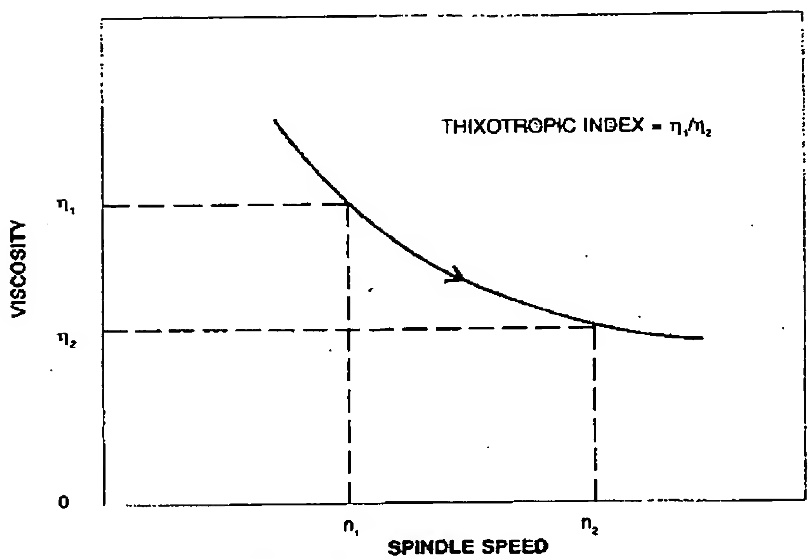


Figure 19: Brookfield viscosity measurements

CAB-O-SIL Fumed Silica Versus Precipitated Silica

In Figure 20 and Table 4 the theological and reinforcement properties of a precipitated silica with a surface area of 136 m^2/g have been compared with those imparted by a 108 m^2/g CAB-O-SIL® L-90 fumed silica in a silicone rubber RTV-1 sealant. The CAB-O-SIL L-90 fumed silica imparts a well-defined yield point to the sealant whereas precipitated silica-thickened sealant shows no yield point at either loading (Figure 20). The data in Table 4 again confirms that with the CAB-O-SIL thickened sealant there is no sag and a moderate extrusion rate. In comparison, the precipitated silica-thickened sealants show very high sag values with unacceptably fast extrusion rates. At a 14 phg loading, the sealant thickened with precipitated silica shows a lower viscosity than the sealant containing CAB-O-SIL fumed silica. If the concentration of the precipitated silica is doubled, the viscosity of the sealant becomes higher than that of the sealant containing CAB-O-SIL, and they both have similar shear thinning index values. However, the sealant containing precipitated silica still shows no yield value (Figure 20), severe sagging and a very high extrusion rate (Table 4).

The significant differences in the rheology control imparted to the sealant by the CAB-O-SIL fumed silica and the precipitated silica are related to the wide differences in their aggregate morphologies. The open-chained structure of the CAB-O-SIL aggregates allows the development of a silica network formation that is superior to the tight, grape-cluster-like aggregates of the precipitated silica. Complete details of this study may be found in the paper, *The Effect of Fumed Silica in RTV-1 Silicone Rubber Sealants.*

In developing new sealants or adhesive systems, or accurately monitoring the theological properties of an existing system, information on both the anti-sag and flow properties can be achieved using cone and plate rheometers. These devices allow the collection of shear stress data under various shear rate conditions. This data can be transformed into anti-sag (yield point) and application data (viscosity at correct shear rates).

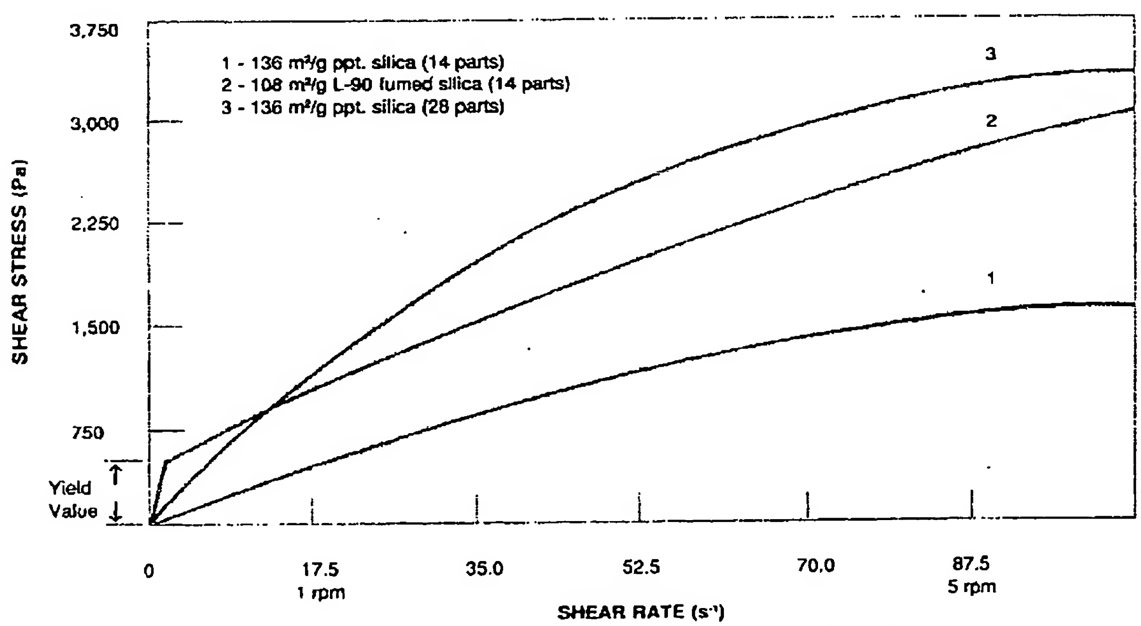


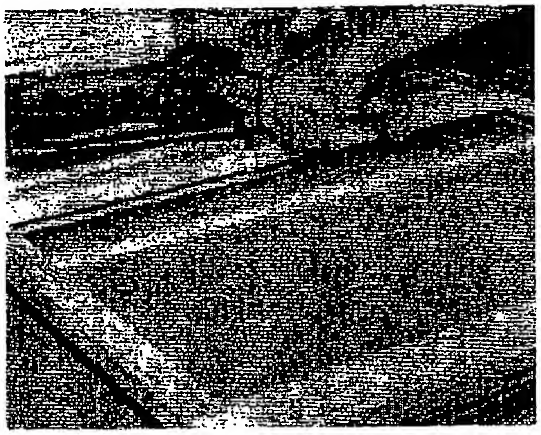
Figure 20: Comparison of rheograms of silicone sealants containing fumed and precipitated silicas

TABLE 4

COMPARISON OF PRECIPITATED SILICAS WITH CAB-O-SIL®FUMED SILICA

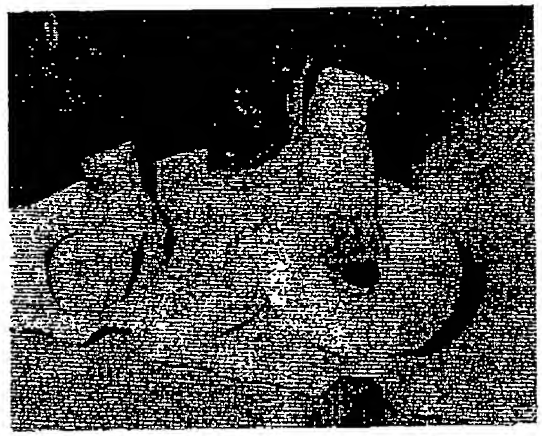
Formulation	1	2	3
Type of Silicas	Fumed (Grade L-90)	Precipitated	Precipitated
Surface Area, m^2/g	108	136	136
Bulk Density, lb./cu. ft.	3.2	11.2	11.2
Loading, Parts	14	14	28
Processing and Theological Properties			
Incorporation Time, min.	11	4	7
Dispersion Level	Excellent	Poor	Poor
Skin Time, min.	26	20	20
Yield Value, Pa	410	0	0
Viscosity, 1 rpm, Pas	45	36.5	49.4
STI	1.5	2	1.5
Slump Value, cm	0	>>5	>>5
Penetration Value (0.1 mm)	120	220	150
Extrusion Rate at 40 psi, g/rein.	250	←Too high to measure→	
Cured Physical Properties			
Shore A Durometer	20	14	22
Die B Tear, kN/m (ppi)	4.4 (25)	3.0 (17)	6.1 (35)
Peel Adhesion, kN/m (ppi)	1.1 (6.0)	0.3 (1.5)	0.7 (4.0)
Modulus @ 50%, MPa (psi)	0.29 (40)	0.21 (30)	0.33 (45)
Tensile, MPa (psi)	1.63 (240)	0.58 (85)	1.52 (220)
Lap Shear, MPa (psi)	1.9 (275)	0.6 (95)	0.6 (95)
% Elongation	450	240	290
Clarity, % T at 500 nm	47	9	5

Use of CAB-O-SIL® Fumed Silica in Various Adhesive and Sealant Systems



Acryl S-M 5522 sealant is applied during the manufacture of a residential window. CAB-O-SIL fumed silica is used to provide precise viscosity and flow control in products manufactured by Schnee-Morehead in Irving, Texas.

Photo courtesy of Schnee-Morehead, Inc.



S-M 5225 tape sealant is used to join roofing panels. CAB-O-SIL fumed silica imparts flow control and adhesive strength to the system.

Photo courtesy of Schnee-Morehead, Inc.

Epoxies

CAB-O-SIL® fumed silica is widely used as a thixotrope for epoxy adhesive and sealant systems. In the past, 200 m²/g and 380 m²/g undensed untreated grades were frequently used. These materials initially impart excellent theological properties, but on prolonged storage or under high temperature cure conditions, they lose their sag resistance properties. The failure mechanism of the thixotrope is believed to be due to the preferential adsorption of the epoxide groups on the surface silanol groups, which reduces the strength of the CAB-O-SIL network in the epoxy system.

CAB-O-SIL TS-720 treated fumed silica with a polydimethylsiloxane fluid (Table 2) solved these theological problems as shown by the data in Figure 21 and Table 5. H is interesting to note that neither CAB-O-SIL TS-610 nor TS-530 are effective substitutes for CAB-O-SIL TS-720 fumed silica. This demonstrates the importance of the surface treating group and the treatment level in controlling the rheology of adhesive and sealant systems. CAB-O-SIL TS-720 fumed silica is widely used in commercial epoxy systems and is the thixotrope of choice as summarized below. Further information on CAB-O-SIL treated fumed silica in epoxies may be found in the paper, *Hydrophobic Fumed Silica as a Rheology Control Agent for Epoxy Adhesives, Sealants.*

THE USE OF CAB-O-SIL FUMED SILICA IN EPOXIES

Sag Control Properties	M-5	TS-720	TS-610	TS-530
Initial	Excellent	Excellent	Excellent	Poor
Aged	Poor	Excellent	Poor	Poor
During high temperature cure	Poor	Excellent	Ñ	Ñ

TABLE 5

EVALUATION OF FRESH AND AGED EPOXY DISPERSIONS CONTAINING 5 WT.% OF THE THIXOTROPES AND CURED AT HIGH TEMPERATURE

50 phr Liquid Polyamide Cured 2 Hours at 60° C

	Maximum Non-sag Film Thickness (roils)			
Thixotrope	Fresh	1 Week	2 Weeks	4 Weeks
CAB-O-SIL®TS-720 fumed silica	60+	60	60	60
CAB-O-SIL M-5 fumed silica	60	1	1	1
Caster Oil Derivative	14	1	1	1
30 phr Aliphatic Amine Cured 3 Hours at 125° C				
CAB-O-SIL TS-720 fumed silica	60+	60+	60+	60
CAB-O-SIL M-5 fumed silica	12	1	1	1
Caster Oil Derivative	3	1	1	1

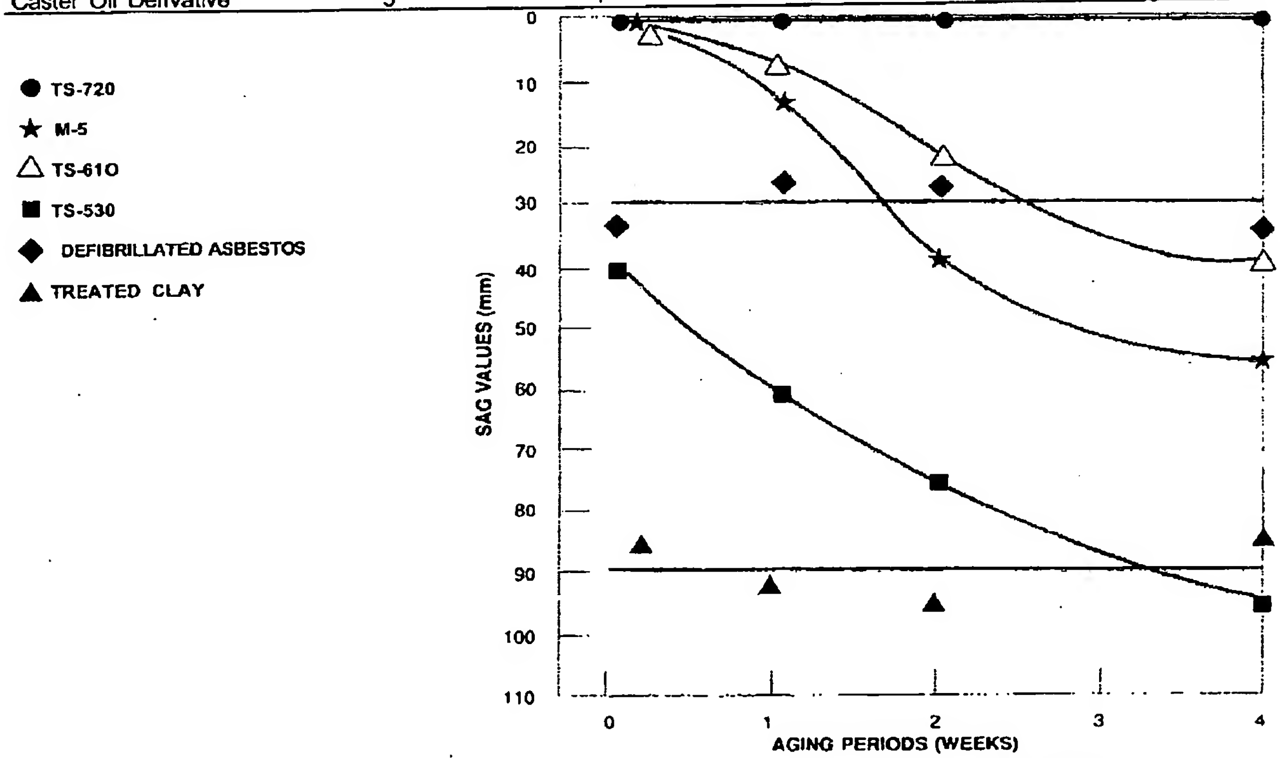
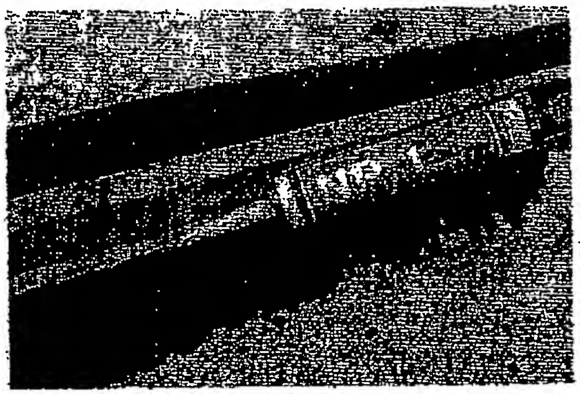


Figure 21: Sag values of epoxy sealants containing 3 wt. % of the various thixotropes after aging at 60°C prior to catalyzation

Polyurethanes

CAB-O-SIL® untreated fumed silicas are used to control the theological properties of one part polyurethane sealants. However, as these are moisture-cure systems, the silica is normally pre-dried prior to use. This is both inconvenient and expensive. Even when the silica is pre-dried, the viscosity of the polyurethane system increases on aging. This is caused by premature crosslinking of the isocyanate groups at the end of the prepolymer chain with the surface silanols on the CAB-O-SIL fumed silica surface.



Sonolastic® NP1 urethane sealant is used to seal roofing joints. CAB-O-SIL fumed silica provides sag resistance to these urethane sealants.

Photo courtesy of ChemRex, Inc.

A series of CAB-O-SIL untreated fumed silicas varying in surface area from 100-380 m^2/g were compared to CAB-O-SIL TS-720 treated fumed silica in a simple one part polyurethane sealant formation. Complete details of this study may be found in the Cabot paper, *The Use of CAB-O-SIL Fumed Silica* in One *Part Polyurethane Sealants*. The results in Table 6 show that the incorporation time increases with increasing surface area, but requires shorter incorporation time than the CAB-O-SIL TS-720. The initial viscosities and sag resistance of the sealants increase as the silica surface area increases. The viscosities increase rapidly over the first 24 hours and then continue to climb slowly on further aging. The CAB-O-SIL TS-720 treated fumed silica imparts good aged sag resistance with moderate viscosity increase. The 100 m^2/g CAB-O-SIL L-90 untreated fumed silica also imparts reasonable aged sag resistance, with modest viscosity build-up on aging. The CAB-O-SIL TS-720 and the 100 m^2/g CAB-O-SIL L-90 also impart slightly lower reinforcement properties (Table 7). Both of these products should be investigated as possible alternatives for the 200 m^2/g CAB-O-SIL M-5 untreated fumed silica which is currently widely used for this application. CAB-O-SIL TS-720 is a logical choice for use in polyurethane as summarized below.

THE USE OF CAB-O-SIL FILMED SILICA IN POLYURETHANES

Property	M-5	TS-720	TS-610	TS-530
Moisture Content	Pre-dry is required	⟵ Use as supplied ⟶		
Sag Resistance	Excellent	Excellent	Good	Fair
Viscosity Stability	Good	Excellent	Excellent	Good
Reinforcement	Excellent	Good	Fair	Good

TABLE 6

THE EFFECT OF CAB-O-SIL® FUMED SILICA SURFACE AREA ON POLYURETHANE SEALANT PROPERTIES

Grade[1]	L-90			M-5			EH-5			TS-530			TS-610			TS-720		
Aging Days	0	1	14	0	1	14	0	1	14	0	1	14	0	1	14	0	1	14
Incorporation Time (min)	4	—	—	5.5	—	—	6	—	—	9	—	—	4	—	—	8	—	—
Boeing sag values (in.)	2.0	0.3	0.2	0.1	0	0	0.6	0	0	2	0.1	0	1.3	0	0	0.3	0.1	0
Brookfield Viscosity[2] (10^3 Pa.s)	275	470	580	1040	1420	1755	780	1970	2235	410	1420	2800	645	1360	1670	575	770	870
Shear thinning index[3]	1.43	1.47	1.51	2.10	2.28	2.54	1.66	2.09	2.48	1.66	1.61	—	1.50	1.68	—	1.51	1.77	1.56
Penetration T=1 sec. (0.1 mm)	370	260	220	200	100	90	230	95	70	265	135	52	220	130	100	230	200	160

[1]All samples aged at room temperature

[2]HA viscometer, T-bar, F, at 5 rpm

[3]The ratio of Haake Model RV3 viscosity measured at 1 rpm to the viscosity at 10 rpm

TABLE 7

THE EFFECT OF CAB-0-SIL®FUMED SILICA SURFACE AREA ON POLYURETHANE SEALANT CURED PHYSICALS

CAB-O-SIL Fumed Silica	L-90	M-5	EH-5	TS-530	TS-610	TS-720
Shore A Durometer	14	19	22	12	10	12
Die B Tear, kN/m (ppi)	10.7 (61)	13.5 (77)	13.7 (78)	10.5 (60)	8.4 (48)	10.0 (57)
Modulus @ 50% MPa (psi)	0.24 (35)	0.35 (50)	0.55 (50)	0.21 (30)	0.17 (25)	0.21 (30)
100% MPa (psi)	0.31 (45)	0.48 (70)	0.48 (70)	0.28 (40)	0.24 (35)	0.28 (40)
Tensile, MPa (psi)	1.7 (250)	2.6 (380)	2.6 (380)	1.5 (210)	1.5 (210)	1.6 (225)
% Elongation	1070	1060	1070	1130	1180	1220

Silicone Systems

Silicone rubber RTV-1 adhesives and sealants are moisture cure systems and hence require starting CAB-O-SIL®fumed silicas with very low moisture contents of <1.0 wt %, and sometimes as low as <0.5 wt. %. Due to this constraint, and to prevent the need for pre-drying the silica, only the lower surface area CAB-O-SIL untreated fumed silica grades <200 m^2/g are normally used.

In Table 8 the results of the evaluation of a series of CAB-O-SIL untreated fumed silicas ranging in surface area from 100-380 m^2/g are shown. The data indicates that there is a general increase in yield value, viscosity and shear thinning index, with increasing surface area. The extrusion rate decreases with increasing surface area, as shown in Figure 22. The reinforcement properties such as 50% modulus (Figure 23), tear strength (Figure 24) and clarity (Figure 25) increase with surface area.

TABLE 8

EFFECT OF CAB-O-SIL FUMED SILICA SURFACE AREA IN A SILICONE RUBBER RTV-1 SEALANT

CAB-O-SIL Fumed Silica	L-90	LM-130	LM-150	M-5	MS-75D	HS-5	EH-5
Surface Area, m^2/g	108	136	164	192	252	336	402
Processing and Theological Properties							
Incorporation Time, min	11	14	20	10	16	14	19
Dispersion Level	←	Excellent	→	←	Good →	← Fair →	
Skin Time, min	26	12	24	24	22	20	14
Yield Value, Pa	410	560	700	700	560	680	530
Viscosity, 1 rpm, Pas	45	65.3	68.7	81.6	71.7	76.4	90.6
STI	1.5	2.1	2.1	2.5	2.2	2.4	2.8
Slump Value, cm	0	0	0	0	0	0	0
Penetration Value, 0.1 mm	v. high	160	140	110	120	140	120
Extrusion Rate, 0.28 MPa, g/rein	250	110	100	80	70	80	70
Cured Physical Properties							
Shore A Durometer	20	20	21	23	24	23	23
Die B Tear, kN/m (ppi)	4.4 (25)	5.1 (29)	5.4 (31)	5.8 (33)	5.8 (33)	5.8 (33)	6.0 (34)
Peel Adhesion, kN/m (ppi)	1.1 (6.0)	1.3 (7:3)	1.1* (6.5*)	1.5 (8.8)	2.2 (12.8)	3.1 (17.5)	1.6* (9.3*)
Modulus @ 50%, MPa (psi)	0.29 (40)	0.30 (45)	0.34 (50)	0.36 (50)	0.36 (50)	0.36 (50)	0.37 (55)
Tensile, MPa (psi)	1.6 (240)	1.4(210)	1.6 (235)	1.7 (250)	1.8 (255)	1.9 (275)	1.6 (230)
Lap Shear, MPa (psi)	1.9 (275)	1.0 (150)	0.8 (1 10)	1.2(170)	1.0 (140)	0.9 (130)	0.6 (85)
% Elongation	450	460	430	440	440	460	410
Clarity, % T at 500 nm	47	57	63	68	69	69	62

All samples showed cohesive failure except* where ~40% adhesive failure occurred

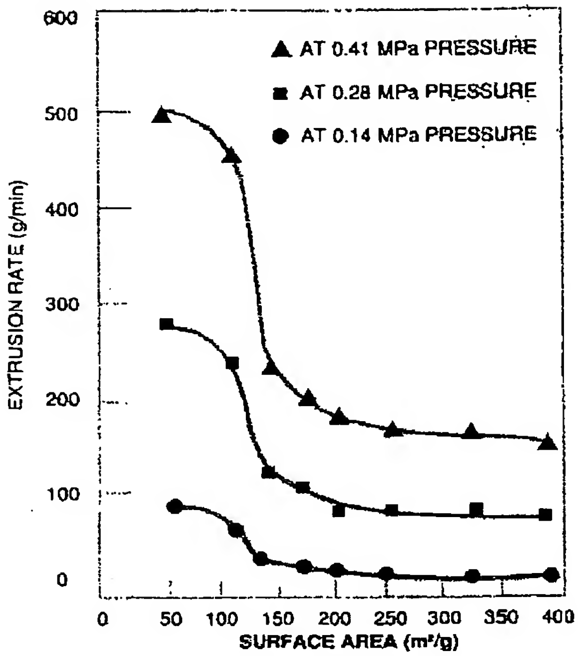


Figure 22: The effect of CAB-O-SIL fumed silica surface area on silicone sealant extrusion rate

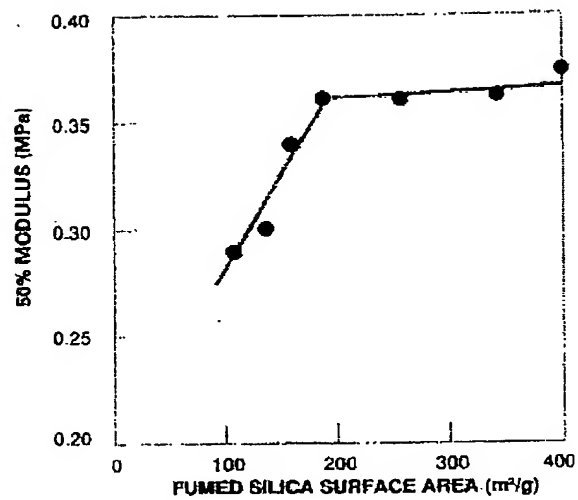


Figure 23: 50% modulus as a function of silica surface area

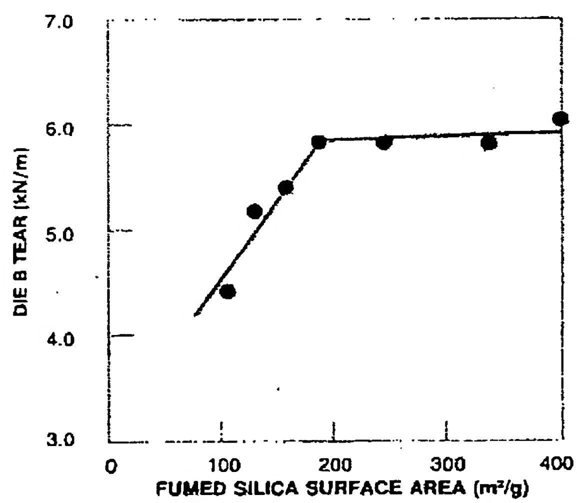


Figure 24: Die B tear as a function of silica surface area

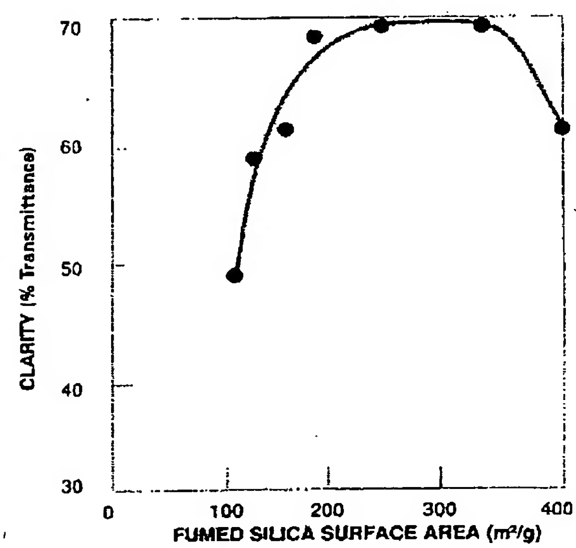


Figure 25: Sealant clarity as a function of silica surface area

The CAB-O-SIL® treated fumed silicas all behave differently in silicone rubber RTV-1 sealants (Table 9) The sealant thickened with CAB-O-SIL TS-610 treated fumed silica has a high yield value, giving good sag resistance and good cured physical properties. The fully treated products, CAB-O-SIL TS-530 and TS-720, impart moderate reinforcement properties to the RTV-1 sealant formulation and have fairly similar viscosity and extrusion properties. However, they impart much lower yield values resulting in poor sag resistance.

CAB-O-SIL TS-610 is normally used only in silicone rubber RTV-1 systems where there is a strong possibility of moisture pick-up on the fumed silica due to either long term storage or high relative humidity. Some silicone rubber compounders use CAB-O-SIL LM-130 and LM-150 fumed silica with special packaging to reduce moisture pick-up. The use of CAB-O-SIL fumed silica in silicone RTV-1 sealants is summarized below.

THE USE OF CAB-O-SIL FUMED SILICA IN SILICONE RUBBER RTV-1 SEALANTS

Property	Untreated Silica 100-200m2/g	TS-610	TS-720	TS-530
Moisture level	< 1 %	← Use as supplied →		
Sag resistance	Excellent	Excellent	Poor	Poor
Extrusion property	Excellent	Excellent	Good	Good
Reinforcement	Excellent	Excellent	Fair	Fair

TABLE 9

EVALUATION OF CAB-O-SIL®TREATED FUMED SILICAS IN A SILICONE RUBBER RTV-1 SEALANT

CAB-O-SIL Fumed Silica	TS-610	TS-530	TS-720
Treatment Agent	Dimethyldichlorosilane	Hexamethyldisilazane	Polydimethylsiloxane
Incorporation Time, min	3.5	2.5	3
Dispersibility	←	Good	→
Yield Value, Pa	410	195	220
Viscosity @ 1 rpm, Pas	43.8	37.4	31.8
STI	1.39	1.02	1.26
Slump Value, cm	0	> 5	> 5
Extrusion Rate 0.28 MPa, g/rein	160	175	260
Cured Physical Properties			
Shore A Durometer	20	16	17
Die B Tear, kNm-1 (ppi)	4.2 (24)	3.5 (20)	3.5 (20)
Modulus @ 50% MPa (psi)	0.31 (45)	0.28 (40)	0.28 (40)
Peel Adhesion, kNm-1 (ppi)	1.0 (5.5)	1.2 (6.8)	0.9 (5.0)
Lap Shear, MPa (psi)	1.9 (280)	1.9 (280)	1.9 (280)
Tensile, MPa (psi)	1.4 (205)	0.79 (1 15)	1.0 (150)
% Elongation	405	305	350
Clarity, % Tat 500 nm	66	62	55

Other Systems

CAB-O-SIL®fumed silica is also used as a flow control and reinforcing filler in many other types of adhesives and sealants, including those based on acrylic, butyl, polysulphide and block copolymers. The improvement in the bond strengths of various adhesives on the addition of small quantities of CAB-O-SIL are shown in Table 10. Similar data for a Kraton-based pressure-sensitive adhesive are shown in Table 11.

TABLE 10

BOND STRENGTH INCREASE WITH CAB-O-SIL FUMED SILICA

Nonvolatile Component	Fumed Silica (%)	Bond Strength Increase(%)
Butyl Rubber	1.1	7
Neoprene	1.5	43
Natural Rubber	5	60
Polyvinyl Acetate	2	25

TABLE 11

PROPERTIES OF A PRESSURE-SENSITIVE ADHESIVE WITH AND WITHOUT CAB-O-SIL FUMED SILICA

Silica Loading, phr	4	0
Film Thickness, roils	1.5	1.5
Specific Gravity	0.93	0.93
Rolling Ball Tack, cm	0.5	0.5
Probe Tack, kg	2.1	2
Shear Adhesive Failure, 'C	88	88
Tensile, MPa (psi)	5.4 (780)	4.8 (700)
% Elongation	680	660
Shore A Durometer	68	61
Peel Temperature, °C	88	66
116°C Hold, mins	180	100

CAB-O-SIL® Fumed Silica Grade Recommendation Guide

System	Function	Level (wt.%)	Grade
	Adhesives		
Epoxy	Anti-Sag	1.5-3.0	TS-720
RTV-1 Silicone Rubber	Reinforcement	3.0-6.0	L-90/LM-130/ LM-150/TS-610
Polyurethane	Increases Cohesive Strength Improves Theological Properties	2.0-4.0	TS-720/M-5
Pressure Sensitive	Reinforcement	2.0-5.0	M-5
Butyl Rubber	Reinforcement Thixotropy	1.0-3.0	M-5
Neoprene	Reinforcement Thixotropy	1.0-2.0	M-5
Natural Rubber	Reinforcement Thixotropy	4.0-6.0	M-5
Polyvinyl Acetate	Reinforcement Thixotropy	1.0-3.0	M-5
	Sealants		
Epoxy	Anti-Sag Anti-Settling	3.0-7.0	TS-720
Polyurethane	Anti-Sag Anti-Settling Reinforcement	3.0-7.0	TS-720/M-5
RTV-1 Silicone Rubber	Anti-Sag Reinforcement	6.0-12.0	L-90/LM-130/ LM-150/TS-610

Recommended Dispersion Equipment

	Adhesives	Sealants
Increasing Dispersion Capabilities ↓	**Change can**	Dough mixer
	Dispersator blade	Low shear change can
	3 roll mill	High shear change can
		Twin screw extruder mixer

Appendix

FORMULATIONS

Formulation 1: (Tables 3,4,8 and 9)

	Parts
Baysilone® E-18 gum	100
Baysilone® M-1000 non-reactive diluent	50
Baysilone® crosslinking agent 3187	7
Fumed silica	14
Dibutyltindilaurate (DBTDL)	0.03
Total	171.03

Formulation 2: (Figure 21)

Part A	Epon® 828 resin	100
	Calcium carbonate	100
	Thixotrope	6
Part B	Diethylene triamine (DETA)	
Mixture	Part A	100
	Part B	11

Formulation 3: (Table 5)

Part A	Epon® 828 resin	100
	Fumed Silica	5
Part B	Ancamine® 350A liquid polyamide	
Mixture	Part A	100
	Part B	50
Part A	Epon® 828 resin	100
	Fumed Silica	5
Part B	Jeffamine® D-230 aliphatic amine	
Mixture	Part A	100
	Part B	30

Formulation 4: (Tables 6 and 7)

	Parts
Prepolymer base	94.2
Fumed silica	5.0
Adhesion promoter	0.3
Non ionic surfactant	0.3
Dibutyltindilaurate (DBTDL)	0.2
Total	100.0

Formulation 5: (Table 11)

Kraton® G 1650 styrene butadiene elastomer	100
Wingtacl® 95 hydrocarbon resin	200
Nezchem® 140 aeromatic hydrocarbon resin	50
Tufflo® 6206 process oil	100
Butyl Zimate® zinc di-n-butyl dithiocarbamate	2
CAB-O-SIL® fumed silica	21

Registered Trademarks:

[1] Baysilone®—Bayer Corporation

[2] Epon®—Shell Chemical Co.

[3] Ancamine®—Air Products and Chemicals

[4] Jeffamine®—Texaco Chemical Co.

[5] Kraton®—Shell Chemical Co.

[6] Wingtack®—Goodyear Chemicals

[7] Nezchem®—Neville Chemical Co.

[8] Tufflo®--Lyondell Lubricants

[9] Butyl Zimate®—R.T. Vanderbilt